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The preview search task: Evidence for visual marking

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A series of experiments are reviewed providing evidence for the idea that when new visual objects are prioritized, old objects are inhibited by a top-down controlled suppression mechanism—a process referred to as visual marking. Evidence for the top-down aspect of visual marking is presented, by showing that new object prioritization, as measured in the preview paradigm, depends on task settings and available attentional resources. Evidence for the inhibitory aspect is presented, by showing that selection of new items is impaired when these items share features with the old items. Such negative carryover effects occur within as well as between trials. Alternative accounts and the evidence for them is discussed. It is concluded that the various accounts are not mutually exclusive and that the data is best explained by a combination of mechanisms.

There has been much debate on how new object onsets are prioritized in visual search. That they can be prioritized is now beyond reasonable doubt, as numerous researchers have found either advantages in search when the target is defined (or cued) by a new onset, or disadvantages when one of the distractors is defined (or cued) by a new onset (e.g., Folk, Remington, & Johnston, 1992; Remington, Johnston, & Yantis, 1992; Theeuwes, Kramer, Hahn, & Irwin, 1998b; Todd & Kramer, 1994; Yantis & Jonides, 1984). Debates have centred on whether onsets have a special status in this respect (Jonides & Yantis, 1988; Miller, 1989), whether they capture attention in an automatic, bottom-up manner or are subject to top-down control (Atchley, Jones, & Hoffman, 2003; Donk & Theeuwes, 2003; Folk et al., 1992; Gibson & Kelsey, 1998; Peterson, Belopolsky, & Kramer, 2003; Theeuwes, 1991;

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Watson & Humphreys, 2000; Yantis & Jonides, 1984, 1990), and whether new onset prioritization merely involves activation of the new elements or also inhibition of the old elements (Donk & Theeuwes, 2001, 2003; Donk & Verburg, 2004; Olivers & Humphreys, 2003; Watson & Humphreys, 1997; Watson, Humphreys, & Olivers, 2003; see also Jiang, Chun, & Marks, 2002, for an account in terms of temporal grouping). The present paper focuses on the latter two debates. We review existing as well as new evidence in favour of the hypothesized mechanism we have called visual marking. Visual marking is the top-down inhibition of irrelevant old information, in anticipation of the appearance of relevant new information. We propose that this mechanism operates together with (but is not the same as) bottom-up attentional activation by new onsets and grouping by common onset.

THE PREVIEW BENEFIT AND VISUAL MARKING

Watson and Humphreys introduced the preview paradigm to investigate further the mechanisms underlying the selection of new objects (Watson & Humphreys, 1997). Figure 1 illustrates the crucial conditions behind this paradigm, together with idealized results. Typically participants may be given a 1000 ms preview of a set of distractors (e.g., green Hs), before adding a second set of items to the display (e.g., blue A distractors and a blue H target). Once the second set is presented, the display conforms to that used in standard conjunction search tasks. However, in this preview condition, search is much more efficient than in the standard conjunction baseline, in which both green and blue distractors appear simultaneously. In fact, search slopes are often no higher than in a standard single feature baseline, in which only the second set (the blue items) is present. Apparently, participants can use the preview period to ignore the old items and limit their search to the new items only. Thus, although the physical appearance of the distractors does not change, the fact that they appear earlier in time and at different locations than targets reduces their influence on selection (see also Treisman, Kahneman, & Burkell, 1983).

In explaining the preview benefit, Watson and Humphreys (1997) proposed that the old items are inhibited in anticipation of the new items—a mechanism referred to as visual marking. They further found that the preview benefit was disrupted when participants performed a secondary task during the preview period. Consequently, visual marking was envisaged as a top-down process: The inhibition is only applied when necessary and when there are sufficient attentional resources.

The present paper consists of three parts. In the first part, we summarize evidence for the top-down aspect of new object prioritization, showing that the preview benefit depends on task requirements and attentional resources.

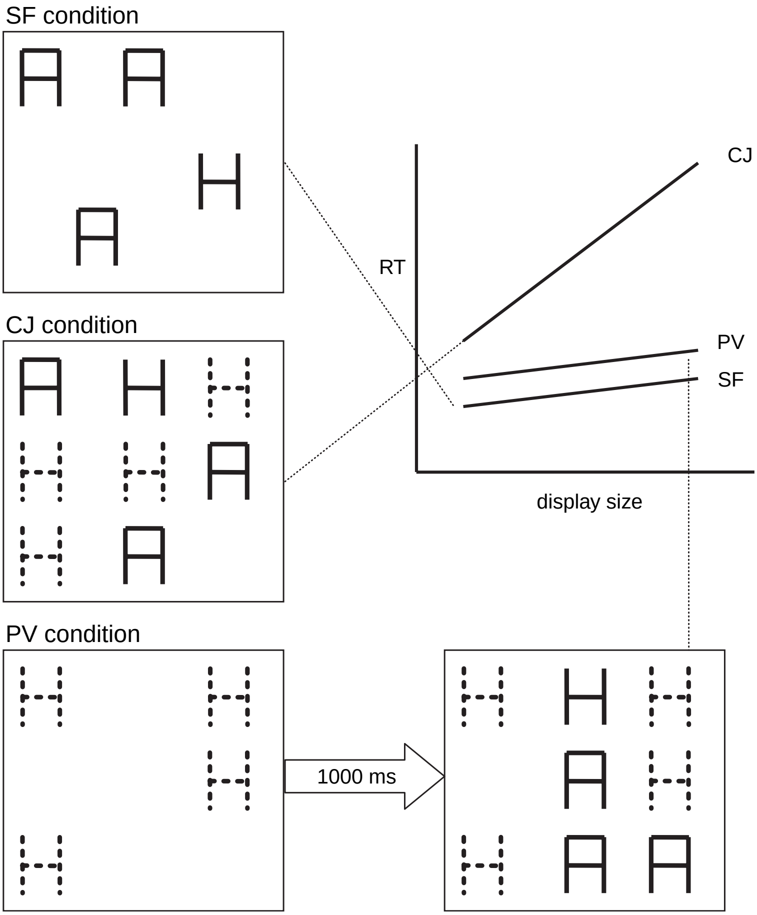

Figure 1. Schematic representation of the preview paradigm and its typical results. In the single feature (SF) condition, the target is a blue H amongst blue A distractors. In the conjunction (CJ) condition the target is a blue H amongst blue As and green Hs. In the preview (PV) condition, the green Hs are presented first for 1000 ms, followed by the addition of the blue set. Note that the PV search slope resembles that of the SF rather than the CJ condition. The results here are idealized for illustration purposes.

In the second part, we summarize evidence for the inhibitory aspect of new object prioritization, showing that ignoring old items may have negative effects on new items when they share a feature or location with the old items. Together, the evidence supports the visual marking hypothesis. In the third and final part we discuss alternative accounts of the preview benefit, such as the automatic onset capture account (Donk & Theeuwes, 2001), and the temporal grouping account (Jiang et al., 2002).

SELECTION OF NEW ONSETS IS SUBJECT TO TOP-DOWN CONTROL

The study of new onset prioritization was kickstarted by the work of Yantis and Jonides (1984), who found that, in visual search, items defined by an abrupt new onset received priority over items defined by an offset, even when the target was unlikely to be defined by an onset. Yantis and Jonides concluded that the abrupt onsets captured attention automatically. However, later studies have suggested that abrupt onset capture may at least partly be subject to top-down control (e.g., Folk et al., 1992; Gibson & Kelsey, 1998). For instance, Yantis and Jonides (1990) themselves showed that abrupt onsets do not capture attention if observers are focused on a specific location.

Several studies have now shown that the prioritization of new objects in the preview paradigm is similarly under the influence of top-down control. In one of the first experiments, Watson and Humphreys (1997) showed that the preview benefit was disrupted when participants performed the additional task of shadowing a series of digits presented at the centre of the preview display. Apparently, the secondary task required attentional resources that were otherwise used to prioritize the new items. This goes against the idea that new items are prioritized completely automatically. One potential problem with this study was that there was not only an additional task during the preview period, but there were also additional visual stimuli in the display. This may have disrupted the preview on a lower, more sensoric level, rather than on a more central attentional resource level. To control for this, Olivers and Humphreys (2002) presented the secondary task before rather than during the preview period, manipulating available resources by inducing an attentional blink (i.e., the unavailability of attention for about 500 ms due to the processing of an earlier target; Raymond, Shapiro, & Arnell, 1992). They found that the preview benefit was completely abolished when the previewed items were presented inside the attentional blink period. Similarly, Humphreys, Watson, and Jolicoeur (2002) have found disruptions of new object prioritization not only with a visual, but also with an auditory secondary task, which suggests again that more central attentional resources are required during the preview.

Additional evidence for top-down control in preview search comes from studies showing that the prioritization of new items is task dependent. In one experiment, Watson and Humphreys (2000) occasionally presented a probe dot on either one of the old or one of the new items and the participant's task was to detect this probe. On the remaining trials the task was to find a visual search target in the new set. As expected, dot detection accuracy for probes presented on old items was worse than on new items, indicating that the latter were prioritized. Interestingly, the difference between old and new items almost disappeared when the task changed so that probe dots were to be detected on all trials (and the visual search target became irrelevant). This provides direct support for the idea that new onset prioritization is task-dependent. Similar results for both response times (RTs) and accuracy data have been reported by Olivers and Humphreys (2002) and Humphreys, Jung-Stalmann, and Olivers (2004). Finally, Olivers, Humphreys, Heinke, and Cooper (2002) found that new onsets were less strongly (or not at all) prioritized when the old items had just previously been relevant to the observer, either because a target was possibly hidden among the old items, or because these items were required for another task such as estimating their number. Together, these results support the idea that new onset prioritization is subject to intentional, and attentional, control.

SELECTION OF NEW ONSETS IS SUBJECT TO INHIBITORY CARRYOVER EFFECTS

Another line of evidence in favour of the visual marking account involves inhibitory carryover effects from one stimulus to the other. Several studies now show that the selection of new items is hampered if they share features such as colour, orientation, location, and possibly other properties, with previewed distractors. The findings suggest that visual marking makes use of these features to effectively ignore irrelevant information. The approach is very much reminiscent of the negative priming paradigm, in which a distractor presented on one trial becomes the target on the next. The typical finding is that processing of this target is delayed relative to targets that are unrelated to previous trials (e.g., Tipper, 1985), suggesting its representation is inhibited. Here we will review evidence for carryover effects between trials as well as between old and new sets within a trial.

Between-trial carryover effects

Direct evidence for an inhibitory mechanism comes from a study by Olivers and Humphreys (2002, Exp. 4). Figure 2 shows a schematic representation of the tasks involved. The participant's first task was to identify a target letter from a stream of letters presented rapidly and serially at fixation (a so-called RSVP stream). This task typically induces an attentional blink, a temporary lapse of attention of up to about 500 ms (Raymond et al., 1992). Immediately following the RSVP stream, a preview of green H distractors was presented for 450 ms, followed by a set of blue items. The second task was to search for a blue H target in this second set. Crucially, by presenting the RSVP target either early or late in the stream, the previewed distractors could be moved either outside or inside the attentional blink period. We

Figure 2. Schematic representation of the combined rapid serial visual presentation (RSVP) and preview task used in Experiment 4 of Olivers and Humphreys (2002). Adapted from Olivers and Humphreys (2002) with permission from Elsevier.

hypothesized that the attentional blink, when induced late in the stream, would take away vital attentional resources from the top-down inhibition mechanism applied to the previewed green Hs. Consequently, the search for the blue H would be slowed by the presence of unsuppressed distractors. This was exactly the result, as is shown by the top line in Figure 3: RTs to blue H targets were longer when green H distractors had been presented inside the blink compared to outside the blink. More important in the present context however was the effect on the next trial. This trial never involved an RSVP task, but instead a simple search for a green H target amongst green A distractors. Note that the target on this task was the same as the previewed distractors on the previous trial. The argument was again that when the green H distractors were presented outside the blink on the previous trial, they received stronger inhibition than when presented inside the blink. If so, turning them into the target on the subsequent trial might slow down search relative to when there were insufficient resources to suppress them in the first place. The results confirmed this hypothesis, as shown by the bottom line in Figure 3. Search was slower for green H targets when green H distractors had previously been presented outside the blink. This finding suggests some suppression was carried over from one trial to the next, on the basis of shared colour, or perhaps shared form. Taken

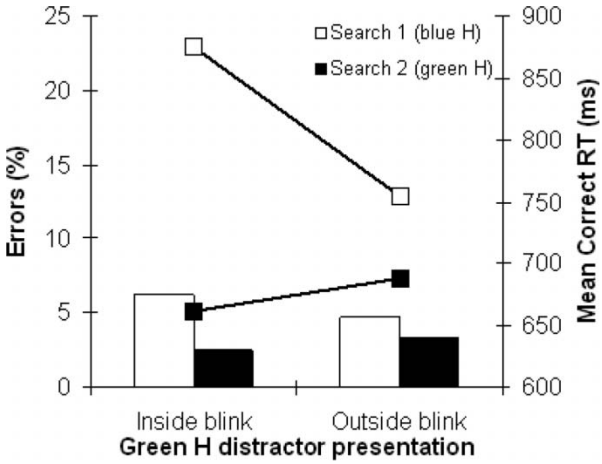

Figure 3. Results from Experiment 4 of Olivers and Humphreys (2002). Adapted from Olivers and Humphreys (2002) with permission from Elsevier.

together the results provide direct evidence for a resource-limited inhibitory mechanism applied to old items, as proposed under the visual marking hypothesis. They also indicate that this mechanism is at least in part feature based.

Similar conclusions can be drawn from a previously unpublished experiment. In this experiment, 58 participants (mean age 22.8 years, range 18–39) previewed one set of items for 300 ms, and searched a second set of items on each trial. The two sets differed in both colour and orientation, and the target was defined by the direction of an arrow (left/right) on one of the new bars (see Figure 4 for some example displays). The crucial factor was the relationship between two consecutive trials. In the unrelated condition, the two sets on any trial n would differ in both colour and orientation from the two sets on trial $n-1$. In the repeat first set condition, the first set of trial n was the same as the first set of trial $n-1$ (in colour and orientation, but not necessarily location, as bars were randomly repositioned). In the first set becomes second condition, the second set on trial n was the same as the first set of trial $n-1$ (again, in colour and orientation, not location). We hypothesized that, if the first set is being inhibited and some of this inhibition persists across trials, repeating the first set would result in a benefit relative to unrelated trials, since the same information is inhibited again. In contrast, when the inhibited items become the to-be-searched items, we may expect a cost relative to unrelated trials. Figure 5 shows the mean RTs for correct trials of each trial type (unrelated, repeat first set, first set becomes second). An ANOVA revealed that RTs varied significantly with trial type, $F(2, 114) = 7.87$, $MSE = 3622.9$, $p = .001$. Importantly, RTs were

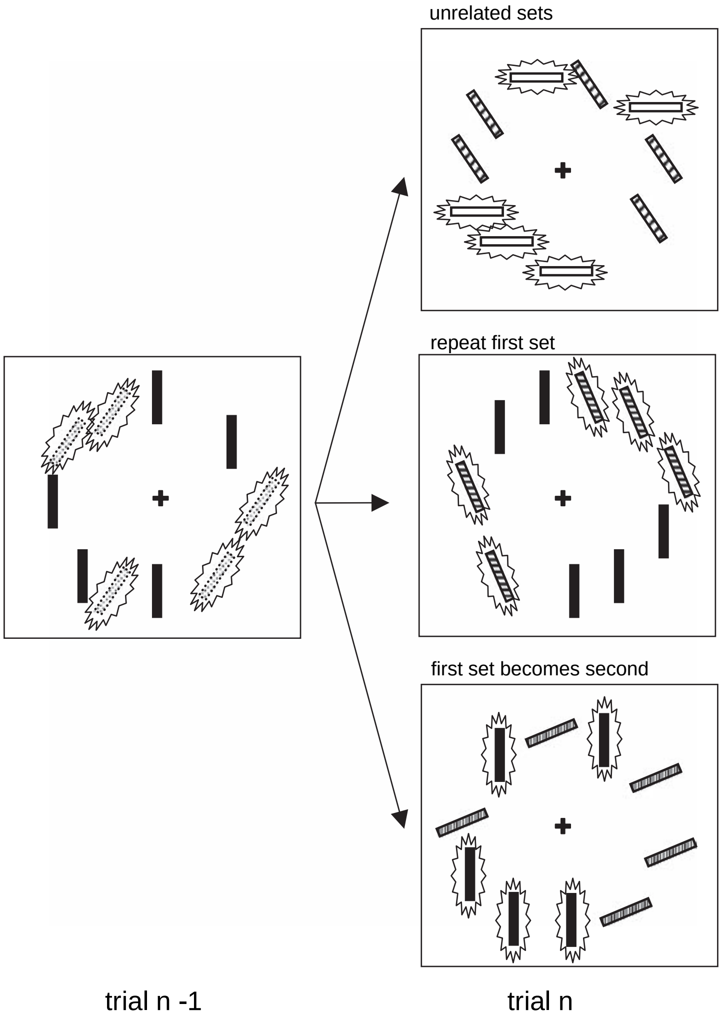

Figure 4. Schematic representation of the different conditions of Experiment 1. The "bangs" represent the new bars. Not drawn here are the small arrows that were present on the centres of the bars. The target bar contained a left- or right-pointing arrow, the other new bars up- or down-pointing arrows. The previewed bars also contained left- or right-pointing arrows. Each trial started with a grey fixation dot followed after 500 ms by two sets of six bars, one presented for 300 ms, before the other was added. The trial ended with a 500 ms blank screen. The bars measured 0.18 degrees wide $\times$ 0.72 degrees tall and their centres were randomly placed on the perimeter of a virtual circle with a radius of 3.80 degrees from fixation. The two sets differed in colour (red, green, blue, yellow, pink, grey, which were isoluminant for the first author) as well as orientation (starting from vertical, rotated 0, 22.5, 45, 67.5, 90, 112.5, 135, and 157.5 degrees). Colour and orientation were selected pseudorandomly depending on the intertrial relationship.

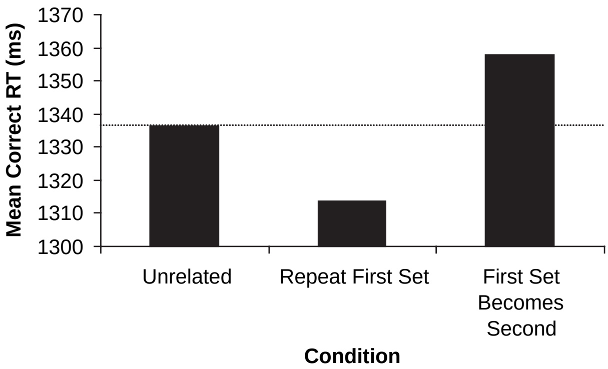

Figure 5. RT results of the intertrial carryover experiment reported in the main text, when item colour and orientation were unrelated to the previous trial, when items in the first set were the same as items in the first set of the previous trial, and when items in the second set were the same as items in the first set of the previous trial. Adapted from Olivers and Humphreys (2003) with permission from Elsevier.

indeed faster, by 23 ms, when the first (old) set was repeated compared to when sets were unrelated, $t(57) = 2.06$, $p < .05$. In contrast, RTs were slower, by 21 ms, when the searched (second) set had been the ignored (first) set on the previous trial, $t(57) = 2.01$, $p < .05$. The error rates were stable across conditions, as 3.50% errors were made in the unrelated condition, 3.55% in the repeat first set condition, and 3.44% in the first set becomes second condition. These results provide further evidence for the idea that previewed items are inhibited, as is put forward by the visual marking hypothesis. Apparently, some of this inhibition persists across trials, resulting in more efficient ignoring of distractors when the previewed items are repeated, but less efficient search when the previewed items turn into the to-be-searched items.

Within-trial carryover effects

In addition to the between-trial carryover effects, other work indicates that similar carryover effects occur between sets within a trial. Braithwaite and colleagues (Braithwaite & Humphreys, 2003; Braithwaite, Humphreys, & Hodsoll, 2003; see also Gibson & Jiang, 2001) had participants search for either one of two target letters ("N" or "Z") amongst a set of random distractor letters, all of which could appear in various colours. This is typically a slow and inefficient task. However, in line with previous work (e.g., Kaptein, Theeuwes, & van der Heijden, 1995), search was much improved by giving the participant information on the target's colour (even though it was not the only item in the display sporting that colour). Search also improved by presenting a preview of distractors, as observers could limit their search to the new set. In fact, search was most efficient when there was a preview and knowledge about the target's colour, indicating that observers made use of both types of information at the same time. However, search efficiency suffered when the target had the same colour as the previewed items relative to when it had a different colour. This was true regardless of whether or not the participant knew the target's colour, that is, the beneficial effects of target colour knowledge and the detrimental effects of target—distractor colour sharing were additive. Braithwaite et al. (2003) therefore concluded that observers may employ two types of attentional set: A "positive" (excitatory) set for the to-be-searched target colour, and a "negative" (inhibitory) set for the to-be-ignored distractor colour. When an item carries a to-be-ignored as well as a to-be-found feature, the net result may be that the two sets cancel each other out.

Similar ideas were put forward by Olivers and Humphreys (2003) on the basis of the effects distractor previews had on the attentional capture by unique targets and distractors (often called singletons; Pashler, 1988). Olivers and Humphreys (2003) presented participants with preview tasks in which, as before, one set of distractors was shown first, followed by the addition of another set of distractors, including a target. Either the target or one of the new distractors could be a singleton, carrying a salient colour and/or orientation. Figure 6 illustrates some of the conditions. Note that the singleton was always in the second set, and it was also always unique relative to this second set. Olivers and Humphreys argued that if the second (new) set is simply prioritized directly, without observers having to inhibit the preview, the singleton should retain its attention-guiding capacity and lead to benefits in search when it is a target, and to costs when it is a distractor. If, however, previewed items are suppressed, and some of this suppression is carried over to the new display on the basis of feature similarity, then we should expect reduced effects from singletons that share features with the old items. Figure 7 shows the typical costs when the singleton was a distractor, for conditions in which there was no preview (i.e., the single feature condition), in which there was a preview of 1000 ms which stayed on, in which there was a 1000 ms preview but one that switched off when the new items appeared, and in which there was a 100ms preview, again switching off as soon as the new items appeared. Singletons possessing a different colour than the previewed items retained their attention capturing capacity, as costs remained constant across the conditions. In contrast, singleton costs were much reduced when the singleton shared its colour with the previewed items—even when the previewed items had already been switched off by the time the singleton appeared. Similar effects were found for singleton targets (not shown here).

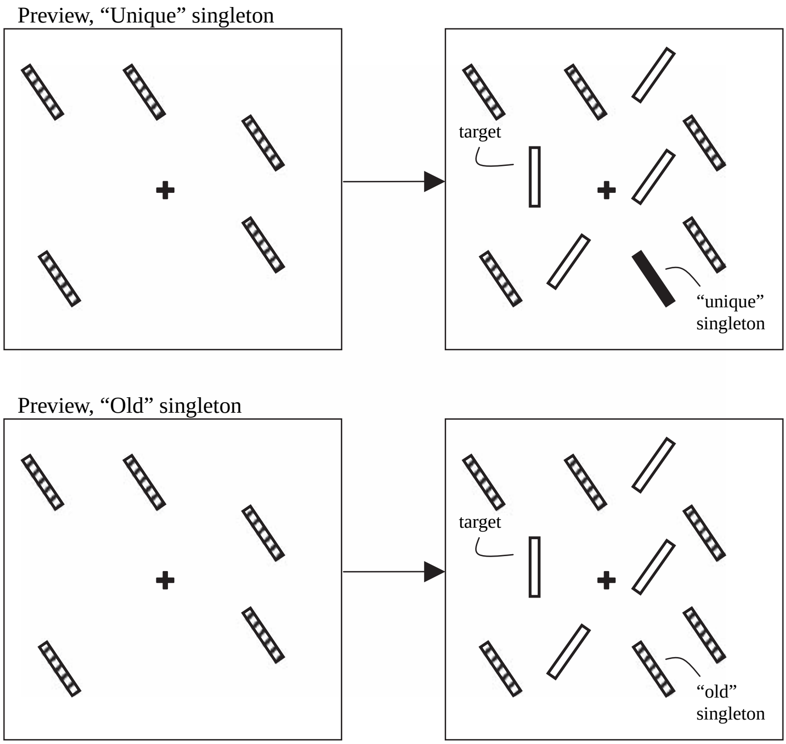

Figure 6. Stimulus examples from the singleton inhibition paradigm of Olivers and Humphreys (2003). Adapted from Olivers and Humphreys (2003) with permission from Elsevier.

The idea of two attentional sets, one for the target information, one for the distractor information, was also proposed by Theeuwes and Burger (1998). They found that in an inefficient search task, a singleton distractor could be ignored, but only when both the target and distractor colour were known from trial to trial. When either of the two varied, the singleton interfered with search. Theeuwes and Burger concluded that singleton distractors capture attention due to strong bottom-up activation. Only when observers know what to attend to and know what to inhibit can they exert maximum top-down control over selection and eliminate this bottom-up activation caused by singleton distractors.

A final study worth pointing out in this section is one of the first preview experiments looking at within-trial carryover effects, and which actually found no such effects. In this experiment, Watson and Humphreys (1997), Exp. 7) presented an initial preview set of green distractors, followed by a mainly blue target set that also included some additional green distractors. The number of green items in the first and second set was varied, but always

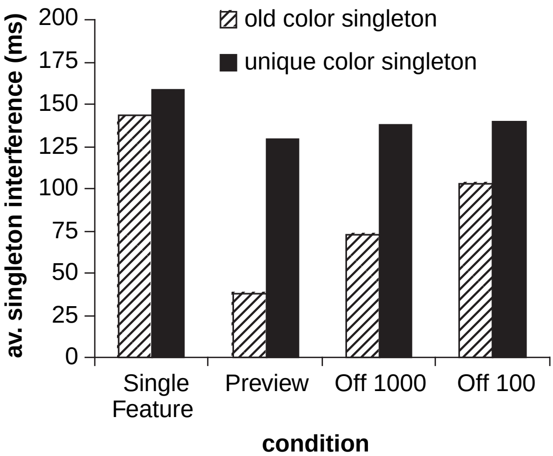

Figure 7. Results for the singleton distractor conditions of Experiment 4 of Olivers and Humphreys (2003). Shown is the average interference caused by singleton distractors in the new (second) set, when this singleton shares its colour with the old items (in the preview conditions) or has a unique colour.

added up to a constant number, so that the more green items there were in the first, the fewer there were in the second. The rationale behind the experiment was that if the old green items are inhibited through their distinguishing feature (i.e., green), the new green items should also be inhibited and therefore not affect search. However, Watson and Humphreys found a systematic effect on search rates of the number of green items in the new set. They concluded that the inhibition was not feature based. Note though that an increase of the number of green items in the new set was confounded with a decrease in the number of green items in the old set. It is possible that the strength of the inhibition depends on the number of items that need to be inhibited. For example, it may be easier to ignore one new green item after having ignored seven old green items than to ignore seven new items after having ignored only one old green item. Moreover, even though the new green items may have been suppressed, this does not mean they could not compete at all in search. Any inhibition may have been counteracted by onset-related activation (either top down or bottom up).

Location- or object-based carryover effects

So far, we have discussed between- and within-trial carryover effects on the basis of feature similarity. In a way, the probe dot studies referred to earlier provide another version of these effects. Of special interest is the study by Humphreys et al. (2004). They found that the detection of dots occasionally presented on old items not only suffered relative to new items, but also relative to dots presented on an empty background grid (the grid was present to control for luminance masking). These costs relative to the background were already present before the new items appeared. If we regard the background as a suitable baseline against which we can measure relative activation and inhibition, then these results provide direct support for the suppression of old items in advance of new onset appearances. Since the probe dots shared neither colour nor shape with the old items, it is likely that this inhibition was either location based (i.e., bound to the old object's location) or object based (i.e., bound to the old object itself).

ALTERNATIVE EXPLANATIONS

Automatic capture by new onsets

Donk and Theeuwes (2001; see also Belopolsky, Theeuwes, & Kramer, 2005; Donk, 2006 this issue; Peterson et al., 2003) have claimed that the preview benefit is not due to the top-down inhibition of old items, but merely the result of the automatic activation of the new items, caused by their abrupt luminance transients (cf. Todd & van Gelder, 1979). Initial support for this claim comes from three experiments in which Donk and Theeuwes (2001) varied the relative luminance of the items to their background. In their first experiment both old and new items were green on an equiluminant grey background. It was found that the number of old items had a substantial effect on search, indicating that they could not be excluded from selection. In the second experiment, the old items were initially presented in green on a (nonequiluminant) black background. The background luminance was then gradually increased so that by the time they appeared, the new elements were equiluminant with the background. Again it was found that the old items affected search efficiency anew items could not be fully prioritized. In the third experiment, the old items were presented on an equiluminant grey background. The background luminance was then gradually lowered, so that by the time they appeared, the new elements were defined by a luminance difference relative to this background. Now the old elements did not affect search and the new elements were completely prioritized. Donk and Theeuwes interpreted these findings as evidence that a luminance onset is required for new items to be prioritized, whereas the relative luminance of the old items does not matter. Furthermore, in a follow-up study, Donk and Theeuwes (2003) showed that new items received priority over old items even when the target was equally likely (or even more likely) to appear in the old set (cf. Yantis & Jonides, 1984), suggesting that the new object priority was automatic rather than top-down controlled.

A number of remarks can be made here. First, although we believe there is sound evidence for the idea that old visual information can be inhibited, we do not take this to imply that the influence of attentional capture by abrupt new onsets should be excluded. We do not wish to deny that capture by new onsets plays an important role, especially when the new onsets are relevant to the task. We simply believe that this mechanism can be augmented by the top-down inhibition of old items. Second, recent studies have suggested that luminance information is not that crucial to obtain a preview benefit. Humphreys et al. (in press) found a preview benefit even though in their displays all items were, on average, equiluminant with each other and with the background grid, while random dynamic luminance noise was added to these displays to further mask any overall luminance differences between items. Furthermore, a recent study by Braithwaite, Humphreys, Watson, and Hulleman (2005) indicates that a preview benefit may be found with equiluminant stimuli if the preview period is extended to 3 s (rather than the typical 1 s), suggesting that the representation (and subsequent inhibition) of equiluminant information may need time to build up. Why Donk and Theeuwes (2001) did not find a preview benefit with their displays remains an open question, but one possibility is that the items were generally quite difficult to distinguish (as is the case with green items on a grey background), or that the gradual ramping up of the background luminance disrupted the preview.

A third remark is that even if new items are prioritized through their onset, it is unlikely that this is a completely stimulus-driven process as proposed by Donk and Theeuwes. As we have outlined above, whether old items are inhibited or not, prioritization of new items is subject to task settings as well as to the availability of attentional resources, indicating a strong top-down component. The fact that Donk and Theeuwes (2003) found that new objects were prioritized even when the target was more likely to be in the old set does not negate a top-down explanation. In their study, the target always appeared together with the new set (even when the target was in the old set; it was then defined by an equiluminant colour change of one of the old items, simultaneous with the appearance of the new set), and the onset capture may thus have been contingent upon the active anticipation of this new set, because this set indicated the beginning of the search task (see Gibson & Kelsey, 1998, for the same argument). In contrast, when participants start searching the old set before the new set appears, prioritization of the new items is disrupted, as was found by Olivers et al. (2002).

Temporal grouping

Jiang, Chun, and Marks (2002) have proposed that the preview benefit is the result of temporal grouping. The old distractors are grouped on the basis of their common temporal dynamics (i.e., their common onset), as are the new items. The two groups may thus be separated (and searched) on the basis of their asynchrony. Jiang and Wang (2004) later extended this account by proposing that search through the new items is aided by two mechanisms: One quickly decaying memory for the temporal asynchrony of the new items relative to the old items, and a more persistent visual short-term memory for about four to five new items. Interestingly, several neuroimaging studies have now indicated that bilateral superior (and also inferior) parietal areas play an important role in the preview task relative to single set and full set baseline search tasks (Humphreys, Kyllingsbæk, Watson, Olivers, & Paulson, 2004; Olivers, Smith, Matthews, & Humphreys, 2005; Pollmann et al., 2003). These areas have been thought to be part of a top-down frontoparietal attention and short-term memory network (see for reviews, Corbetta, 1998; Kanwisher & Wojciulik, 2000; Kastner & Ungerleider, 2000), but also to play a role in the spatiotemporal dynamics of stimuli (Coull, Frackowiak, & Frith, 1998; Gottlieb, Kusunoki, & Goldberg, 1998). Recently, we have found additional evidence that the parietal lobe plays a crucial role in distinguishing new from old items (Olivers & Humphreys, 2004). We presented patients suffering from posterior parietal damage with a preview task and compared them to age-matched controls. Whereas the control participants could effectively ignore the old items and prioritize the new set (resulting in a preview benefit), the patients had severe difficulties in detecting the new target, to the extent that there was no benefit and sometimes even a cost relative to a full set baseline in which all items were presented simultaneously. This result held even when search was made easier or when segregation between old and new was promoted by an outline shape drawn around the old items. We concluded that this group of patients has difficulties either with segmenting new from old, or with disengaging from old information after possibly successful segmentation (cf. Petersen, Robinson, & Currie, 1989; Posner, Walker, Friedrich, & Rafal, 1984).

As has been indicated before (e.g., Jiang & Wang, 2004), the (spatio)temporal segmentation account and inhibition account (and also the onset account) are not mutually exclusive. The spatiotemporal segmentation of old and new may be maximized by inhibiting the old group and prioritizing (either automatically or top-down) the new group.

Feature-based inhibition

Most results reviewed here show that visual marking can be feature based, in that it uses colour or orientation to suppress the old information. Other results show it does not have to be feature based. Both Olivers, Watson, and Humphreys (1999) and Theeuwes, Kramer, & Atchley (1998a) demonstrated preview benefits for sets of items that did not differ in colour, or indeed in any basic feature. Under the visual marking account, this could be explained by invoking location-based inhibition mechanisms (see Watson & Humphreys, 1997). It therefore seems that previewed items are suppressed through whatever representation is available, whether features, locations, or both. In contrast, if neither feature nor location information is available, visual marking fails (as shown by Olivers et al., 1999). An alternative explanation, as is proposed by Donk (2006) this issue, is that the feature-based inhibition we found is part of a more general mechanism that operates during various types of attentional selection tasks (e.g., Cepeda, Cave, Bichot, & Kim, 1998) and is therefore not special to the preview. Note that, in this respect, the feature-based carryover effects reviewed here are also reminiscent of the negative priming phenomenon (e.g., Neill, 1977; Tipper, 1985). According to Donk's view, feature-based inhibition operates during, but is not crucial to obtaining, a preview benefit. For a preview benefit, attentional capture by new onsets is sufficient, and feature-based inhibition is merely an additional possibility to refine selection. The prediction then is that when there are no feature differences, there will be no inhibition, just onset capture. Existing studies provide little resolution on this issue, as indeed most studies claiming to provide direct evidence for inhibition also employ feature differences between old and new sets. A number of probe dot studies may come closest to a solution to this matter (Humphreys et al., 2004; Olivers & Humphreys, 2002; Watson & Humphreys, 2000). These studies show that detection of small dots suffers when presented on old (previewed) items relative to new items, and also relative to a (presumably neutral) background. Since the probe dots do not share features with the previewed objects, and performance is contingent on the positions of the probes (close to old vs. new distractors), one may argue that the inhibition is location based, and not just a byproduct of more general feature-based selection mechanisms. However, it needs to be pointed out that, so far, the probe studies too have used displays containing colour and/or orientation differences between old and new sets, thus allowing feature-based effects back in. A stronger test would be to present probes on old items that cannot be distinguished from new items except for their moment of onset. The visual marking account predicts that probe detection should still suffer. Finally, the idea that visual marking is just another case of a more general inhibitory mechanism is not an unattractive proposal. It would mean that the mechanism behind visual marking does not represent a special case solely applicable to previews, but instead reflects a universal top-down inhibitory process that can be applied to distracting information presented at any moment in time, whether simultaneous with or in advance of the target information (see Peterson et al., 2003). Such a mechanism would make sense in an efficient yet flexible cognitive system.

CONCLUSION

We have reviewed evidence showing that previewing certain items affects the selection of other items presented later in time. These effects occur between, as well as within trials, and depend on the feature similarity between old and new items. We have also reviewed evidence showing that presenting an additional task either before or during the preview affects the selection of the new items, showing that prioritization of new items requires limited resources. Finally, we have reviewed evidence showing that deprioritization of the old, and prioritization of the new, is dependent on overall task settings. Taken together, we interpret these findings as evidence for an inhibitory process applied to old visual information, which may augment more automatic attentional capture mechanisms, as well as temporal segmentation processes. We propose that the attention system may employ two attentional sets; one positive set for target properties, one negative set for distractor properties. Future studies will need to address further how these attentional sets interact across features, space, and time.

REFERENCES

Atchley, P., Jones, S. E., & Hoffman, L. (2003). Visual marking: A convergence of goal- and stimulus-driven processes during visual search. *Perception and Psychophysics*, *65*(5), 667–677.

Belopolsky, A. V., Theeuwes, J., & Kramer, A. F. (2005). Prioritization by transients in visual search. *Psychonomic Bulletin and Review*, *12*, 93–99.

Braithwaite, J. J., & Humphreys, G. W. (2003). Inhibition and anticipation in visual search: Evidence from effects of color foreknowledge on preview search. *Perception and Psychophysics*, *65*(2), 213–237.

Braithwaite, J. J., Humphreys, G. W., & Hodsoll, J. (2003). Ignoring color over time: The selective effects of color on preview-based visual search of static items. *Journal of Experimental Psychology: Human Perception and Performance*, *29*, 758–778.

Braithwaite, J. J., Humphreys, G. W., Watson, D. G., & Hulleman, J. (2005). Revisiting preview search at isoluminance: New onsets are not necessary for the preview advantage. *Perception & Psychophysics, 67,* 1214–1228.

Cepeda, N. J., Cave, K. R., Bichot, N. P., & Kim, M. S. (1998). Spatial selection via feature driven inhibition of distractor locations. *Perception and Psychophysics*, *60*, 727–746.

Corbetta, M. (1998). Frontoparietal cortical networks for directing attention and the eye to visual locations: Identical, independent, or overlapping neural systems? *Proceedings of the National Academy of Sciences, USA*, *95*, 831–838.

Coull, J. T., Frackowiak, R. S. J., & Frith, C. D. (1998). Monitoring for target objects: Activation of right frontal and parietal cortices with increasing time on task. *Neuropsychologia*, *36*(12), 1325–1334.

Donk, M. (2006). The preview benefit: Visual marking, feature-based inhibition, temporal segregation, or onset capture? *Visual Cognition*, *14*, 736–748.

Donk, M., & Theeuwes, J. (2001). Visual marking beside the mark: Prioritizing selection by abrupt onsets. *Perception and Psychophysics*, *63*(5), 891–900.

Donk, M., & Theeuwes, J. (2003). Prioritizing selection of new elements: Bottom-up versus top-down control. *Perception and Psychophysics*, *65*(8), 1231–1242.

Donk, M., & Verburg, R. C. (2004). Prioritizing new elements with a brief preview period: Evidence against visual marking. *Psychonomic Bulletin and Review*, *11*, 282–288.

Folk, C., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 1030–1044.

Gibson, B. S., & Jiang, Y. (2001). Visual marking and the perception of salience in visual search. *Perception and Psychophysics*, *63*, 59–73.

Gibson, B. S., & Kelsey, E. M. (1998). Stimulus-driven attentional capture is contingent on attentional set for displaywide visual features. *Perception and Psychophysics*, *24*(3), 699–706.

Gottlieb, J. P., Kusunoki, M., & Goldberg, M. E. (1998). The representation of visual salience in monkey parietal cortex. *Nature*, *391*, 481–484.

Humphreys, G. W., Jung-Stalmann, B., & Olivers, C. N. L. (2004). An analysis of the time course of attention in preview search. *Perception and Psychophysics*, *66*, 713–730.

Humphreys, G. W., Kyllingsbæk, S., Watson, D. G., Olivers, C. N. L., & Paulson, X. (2004). Parieto-occipital areas involved in efficient filtering in search: A time course analysis of visual marking using behavioral and functional imaging procedures. *Quarterly Journal of Experimental Psychology*, *57A*, 610–635.

Humphreys, G. W., Watson, D. G., & Jolicoeur, P. (2002). Fractionating the preview benefit in search: Dual task decomposition of visual marking by timing and modality. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(3), 640–660.

Jiang, Y., Chun, M. M., & Marks, L. E. (2002). Visual marking: Selective attention to asynchronous temporal groups. *Journal of Experimental Psychology: Human Perception and Performance*, *28*, 717–730.

Jiang, Y., & Wang, S. W. (2004). What kind of memory supports visual marking? *Journal of Experimental Psychology: Human Perception and Performance*, *30*(1), 79–91.

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception and Psychophysics*, *43*, 346–354.

Kanwisher, N., & Wojciulik, E. (2000). Visual attention: Insights from brain imaging. *Nature Reviews: Neuroscience*, *1*, 91–100.

Kaptein, N. A., Theeuwes, J., & van der Heijden, A. H. C. (1995). Search for a conjunctively defined target can be selectively limited to a color-defined subset of elements. *Journal of Experimental Psychology: Human Perception and Performance*, *21*, 1053–1069.

Kastner, S., & Ungerleider, L. G. (2000). Mechanisms of visual attention in the human cortex. *Annual Review of Neuroscience*, *23*, 315–341.

Miller, J. (1989). The control of attention by abrupt visual onsets and offsets. *Perception and Psychophysics*, *45*, 567–571.

Neill, W. T. (1977). Inhibitory and facilitatory processes in selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *3*, 444–450.

Olivers, C. N. L., & Humphreys, G. W. (2002). When visual marking meets the attentional blink: More evidence for top-down, limited capacity inhibition. *Journal of Experimental Psychology: Human Perception and Performance*, *28*(1), 22–42.

Olivers, C. N. L., & Humphreys, G. W. (2003). Visual marking inhibits singleton capture. *Cognitive Psychology*, *47*, 1–42.

Olivers, C. N. L., & Humphreys, G. W. (2004). Spatiotemporal segregation in visual search: Evidence from parietal lesions. *Journal of Experimental Psychology: Human Perception and Performance*, *30*, 667–688.

Olivers, C. N. L., Humphreys, G. W., Heinke, D., & Cooper, A. C. G. (2002). Prioritization in visual search: Visual marking is not dependent on a mnemonic search. *Perception and Psychophysics*, *64*(4), 540–560.

Olivers, C. N. L., Smith, S., Matthews, P., & Humphreys, G. W. (2005). Prioritizing new over old: An fMRI study of the preview search task. *Human Brain Mapping*, *24*, 69–78.

Olivers, C. N. L., Watson, D. G., & Humphreys, G. W. (1999). Visual marking of locations and feature maps: Evidence from within-dimension defined conjunctions. *Quarterly Journal of Experimental Psychology*, *52A*, 679–715.

Pashler, H. (1988). Cross-dimensional interaction and texture segregation. *Perception and Psychophysics*, *43*, 307–318.

Petersen, S. E., Robinson, D. L., & Currie, J. N. (1989). Influences of lesions of parietal cortex on visual spatial attention in humans. *Experimental Brain Research*, *76*, 267–280.

Peterson, M. S., Belopolsky, A. V., & Kramer, A. F. (2003). Contingent visual marking by transients. *Perception and Psychophysics*, *65*(5), 695–710.

Pollmann, S., Weidner, R., Humphreys, G. W., Olivers, C. N. L., Müller, K., Lohmann, G., et al. (2003). Separating segmentation and target detection in posterior parietal cortex: An event-related fMRI study of visual marking. *NeuroImage*, *18*, 310–323.

Posner, M. I., Walker, J. A., Friedrich, F. J., & Rafal, R. D. (1984). Effects of parietal injury on covert orienting of attention. *Journal of Neuroscience*, *4*, 1863–1874.

Raymond, J. E., Shapiro, K. L., & Arnell, K. M. (1992). Temporary suppression of visual processing in an RSVP task: An attentional blink? *Journal of Experimental Psychology: Human Perception and Performance*, *18*, 849–860.

Remington, R. W., Johnston, J. C., & Yantis, S. (1992). Involuntary attentional capture by abrupt onsets. *Perception and Psychophysics*, *51*, 279–290.

Theeuwes, J. (1991). Exogeneous and endogeneous control of attention: The effect of visual onsets and offsets. *Perception and Psychophysics*, *49*, 83–90.

Theeuwes, J., & Burger, R. (1998). Attentional control during visual search: The effect of irrelevant singletons. *Journal of Experimental Psychology: Human Perception and Performance*, *24*(5), 1342–1353.

Theeuwes, J., Kramer, A. F., & Atchley, P. (1998a). Visual marking of old objects. *Psychonomic Bulletin and Review*, *5*, 130–134.

Theeuwes, J., Kramer, A. F., Hahn, S., & Irwin, D. E. (1998b). Our eyes do not always go where we want them to go: Capture of eyes by new objects. *Psychological Science*, *9*, 379–385.

Tipper, S. P. (1985). The negative priming effect: Inhibitory priming by ignored objects. *Quarterly Journal of Experimental Psychology*, *37A*, 571–590.

Todd, J. T., & van Gelder, P. (1979). Implications of a transient-sustained dichotomy for the measurement of human performance. *Journal of Experimental Psychology: Human Perception and Performance*, *5*, 625–638.

Todd, S., & Kramer, A. F. (1994). Attentional misguidance in visual search. *Perception and Psychophysics*, *56*, 198–210.

Treisman, A., Kahneman, D., & Burkell, J. (1983). Perceptual objects and the cost of filtering. *Perception and Psychophysics*, *33*, 527–532.

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: Prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review*, *104*, 90–122.

Watson, D. G., & Humphreys, G. W. (2000). Visual marking: Evidence for inhibition using a probe-dot paradigm. *Perception and Psychophysics*, *62*, 471–481.

Watson, D. G., Humphreys, G. W., & Olivers, C. N. L. (2003). Visual marking: Using time in visual selection. *Trends in Cognitive Sciences*, *7*(4), 180–186.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: Evidence from visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *10*, 601–621.

Yantis, S., & Jonides, J. (1990). Abrupt visual onsets and selective attention: Voluntary versus automatic allocation. *Journal of Experimental Psychology: Human Perception and Performance*, *16*, 121–134.